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APPLICATION OF A FEASIBLE APPROACH FOR HYDROGEOLOGICAL BOUNDARY MAPPING

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1. ABSTRACT

The Geological Survey of Italy is mandatory charged of the Italian hydrogeological cartography and then is currently involved in aspects regarding the delineation of hydrogeological boundaries of hydrostructures and GWBs. The problem of conducting this process, as much as possible, by objective criteria is a fundamental issue for the realization of consistent hydrogeological maps. The aim of the present work is to illustrate a feasible approach usefully preliminarily applied for delineating hydrogeological boundaries in the test area included in the sheet map N.348 Antrodoco at 1:50.000 scale of the Italian hydrogeological cartographical production.

The proposed approach is based on the application of informative algorithms, usually available in software GIS environment, allowing graphical elaboration on the spatial distribution of electrical conductivity (EC). A good spatial distribution is significant for having an as reduced as possible hydrogeology expert interpretation work on the final elaboration. The EC value distribution organized in GIS vectorial format was submitted to an interpolation process toward a raster file and, then, a surface analysis was performed in order to obtain a contour map with appropriate isoconductivity equidistance. The concluding phase was conducted by superposition of the EC contour lines on a map representing the hydrogeological complex and the tectonic elements within the study area.

2. INTRODUCTION

The Geological Survey of Italy (SGI) has not a mandatory responsibility by the Italian Environment Ministry for WFD/GWD issues, but it is charged of collaborating with the Water Protection Dept. of ISPRA, representing the Unit actually charged of the coordination of the national information collected by the Italian Regions about hydrological data and GWB delineation within the Italian territory. In any case, the SGI is mandatory charged of the hydrogeological cartography of Italy. The definition of international guidelines for the compilation of good quality hydrogeological map legends was attempted from the second half of the last century (e.g., STRUCKMEIER & MARGAT, 1995). In this respect, the SGI is currently involved in aspects regarding the delineation of hydrogeological boundaries for the definition of unitary hydrostructures and GWBs. The problem of conducting this process, as much as possible, by objective criteria is a fundamental issue for the realization of consistent hydrogeological maps and not, for instance, simple elaborations of lithological information taken from geological maps.
The aim of the present work is to illustrate a feasible approach usefully preliminarily applied for delineating hydrogeological boundaries in a test area of the Italian territory characterized by a complex geological-structural and hydrogeological situation (the final stage of this procedure is actually still in progress). This area is represented by the territory included in the sheet map N.348 Antrodoco at 1:50.000 scale of the Italian hydrogeological cartographical production.

3. STRUCTURAL-GEOLOGICAL AND HYDROGEOLOGICAL SETTINGS OF THE TEST AREA

The test area is located between *Lazio* and *Abruzzo* regions (*Rieti* and *L'Aquila* province, respectively; Central Italy). Four main structural units occur in it (Fig. 1). They are the *M.Sibillini*, the *Gran Sasso-Cittareale*, the *M.Giano-M.Gabbia* and the *Acquasanta-Montagna dei Fiori* units (e.g.: BIGI *et alii*, 1991). Outcropping formations belong to stratigraphical sequences of the *Laziale-Abruzzese* Succession (deposition environments passing from marine carbonate platform to slope; Upper Triassic-Paleogene) and of the *Umbro-Marchigiano-Sabina* Succession (Lower Jurassic *p.p.*-Miocene *p.p.*) including its marly-arenaceous Neogenic covers (carbonate platform passing to slope and marine basin environment deposits). Terrigenous turbiditic Tortonian-Messinian formations (evolution towards a foredeep environment of the previously described slope-basin successions) follow up on top (e.g.: BIGI *et alii*, 1991; CENTAMORE *et alii*, 1991; CAPOTORTI *et alii*, 1995; PIANA, 1995; PIERANTONI *et alii*, 2005).
These structural units are separated each other by main regional and local tectonic alignment (e.g., the *Olevano-Antrodoco-Posta-M.Sibillini* overthrust alignment, which is part of the *Ancona-Anzio* regional tectonic alignment as described in the literature; the normal fault cropping next to Pizzoli town; the *M.Cagno-M.Gabbia* overthrust; the normal fault cropping next to the Antrodoco town) (e.g.: BIGI *et alii*, 1991; CENTAMORE *et alii*, 1991; CAPOTORTI *et alii*, 1995; PIANA, 1995; PIERANTONI *et alii*, 2005).
The terrains outcropping in the study area have been grouped, on the basis of relative hydraulic permeability and other hydrogeological features, in the following main hydrogeological complexes (from top to bottom; Fig. 1; AMANTI et alii, 2011):
- *Alluvial complex,* scarce relative permeability, it hosts aquifers of variable importance.
- *Conglomeratic-sandy and detritic complex,* intermediate to scarce relative permeability, it hosts local aquifers.
- *Flysch complex,* scarce relative permeability, it hosts local and perched aquifers.
- *Marly-calcareous and marly complex,* scarce relative permeability, it may host small local aquifers.
- *Calcareous-marly complex,* intermediate relative permeability, it hosts local and perched aquifers.
- *Calcareous complex*, high relative permeability degree, it hosts productive regional basal and perched aquifers.
- *Dolomitic complex*, low to medium relative permeability degree, it includes local aquifers of variable potentiality.

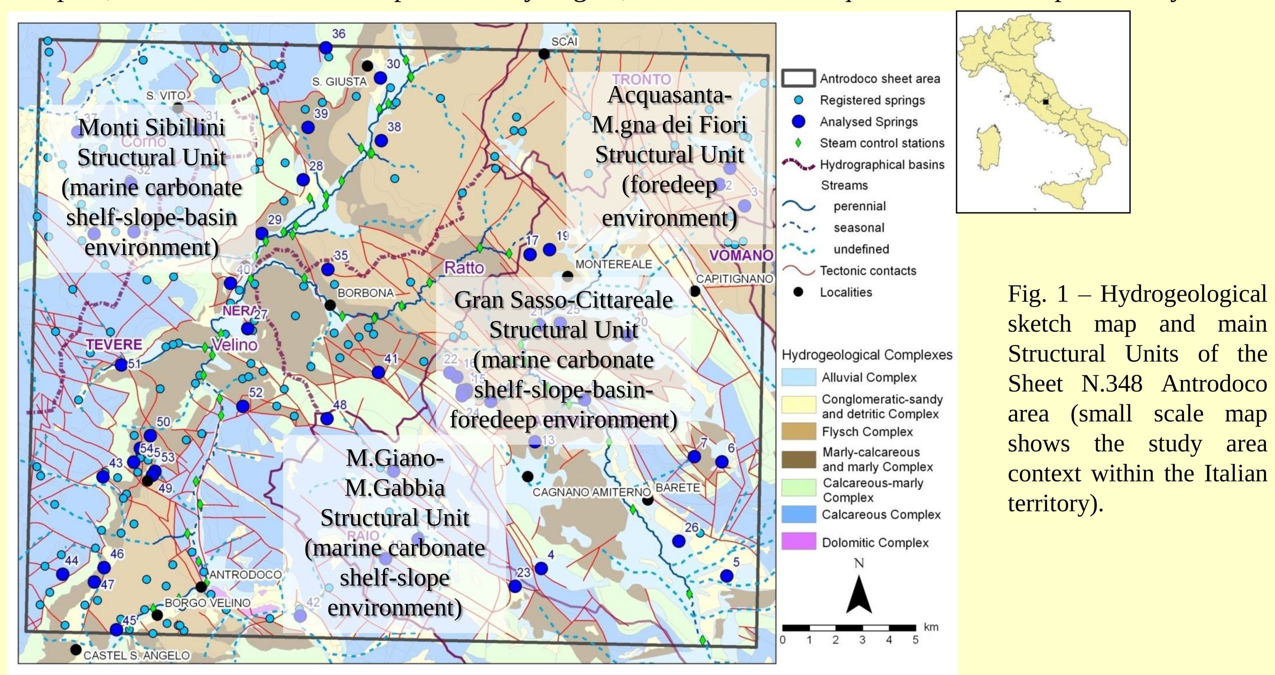

Fig. 1 – Hydrogeological sketch map and main Structural Units of the Sheet N.348 Antrodoco area (small scale map shows the study area context within the Italian territory).

4. GENERAL PROCEDURAL APPROACH

The proposed approach for the hydrogeological boundary mapping has been applied in the test area for the delineation of hydrostructure boundaries according to objective and feasible criteria. The aim of this approach is to avoid, as much as it is possible, a direct derivation of the hydrostructure delimitation (but any other kind of spatial areal element may be traced following this criterion) by simply joining of geological polygons resulted from geological and/or lithological maps, thus giving just the appearance of a generalized geological map to the ensuing hydrogeological cartography. Obviously, this is not useful for an exhaustive and specific representation and understanding of the hydrogeological features of a study territory.

Thus, the proposed approach is based on the application of informative algorithms, usually available in software GIS environment, allowing graphical elaboration on the spatial distribution of some hydrogeological parameters. A first step consists in the selection of the more representative hydrogeological parameter, among the available ones, having the most homogeneous distribution within the studied territory. In particular, the need of a good spatial distribution is significant for having an as reduced as possible hydrogeology expert interpretation work on the elaboration process, since the interpretation will be more intense for sectors which the data are lacking in. For the detailed refinement of the final tracing of the boundaries, on the contrary, the hydrogeological interpretation work is obviously fundamental. During this final operation, geological, tectonic and other supposed and buried elements must be considered in order to outline the boundaries themselves. The reiteration of the elaboration for different parameters may allow a refinement in the realization of the boundary delineation.

GIS software has been used in this approach as useful tools for database organization and the following graphical/cartographical elaborations (Fig. 2).

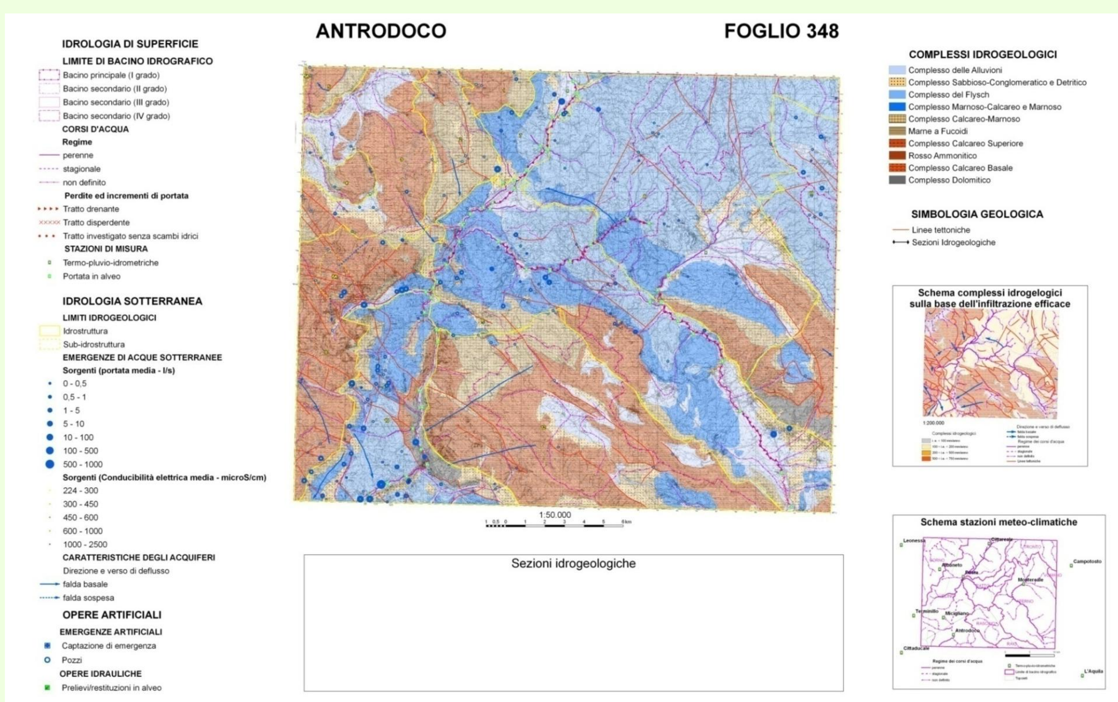

Fig. 2 –Preliminary Hydrogeological Map of Italy of the Sheet 348 Antrodoco (from AMANTI et alii, 2011). The available hydrogeological parameters having the most homogeneous distribution within the studied territory have been selected after the organization of a database linked to GIS software, already available for hydrogeological mapping purposes.

5. METHODOLOGICAL ASPECTS AND RESULTS

The main specific aspects of the methodological approach will be shown in this section. The first action has been the analysis of the appropriateness of the statistical distribution frequency of the selected parameter values, i.e. the spring water electrical conductivity (EC; Fig. 3). The reliability of selecting this parameter for mapping purposes has been verified analyzing its main groups of peaks of distribution, which have been conveniently confirmed to be correlated to specific hydrogeological complexes in various sectors within the map. Furthermore, the estimated spatial distribution of about 1 control point each 2-3 km^2 within the total territory of the sheet (about 605 km^2) has been assumed to be on the whole sufficiently representative for the application of this methodological approach.
The second step has been the preparation of a shapefile with the geographical and quantitative attributes of each registered water point of the control network. In this way we obtained a map with the EC values associated to each control point to be promptly elaborated by GIS software (Fig. 4). Then, the EC value distribution, organized in GIS vectorial format, has been submitted to an interpolation process toward a raster file, obtaining a series of influence areas of homogeneously grouped values of EC (Fig. 5). Then, a surface analysis has been performed in order to obtain a contour map in which the appropriate isoconductivity equidistance has been chosen to have the most reliable ranges of values (already evidenced in fig. 3 and consequently adopted) leading to weighted groups of springs having similar EC (Fig. 6).
So far, the subjective interference of the specialist in hydrogeology in the process was very subordinate, but, hereinafter, the contribution of the specialist begins to be essential for a detailed recognition of the preliminary tracing of the boundaries (i.e., following the position of tectonic elements, geological boundaries, etc.). For the present study this latter phase has been conducted by overlapping the EC contour lines on a map representing the hydrogeological complexes and the tectonic elements within the study area (Fig. 7).
The final tracing of the boundaries (still in progress) is under realization by a detailed comparison between the obtained contour lines and the EC values distribution in the map. This operation allows also to understand in which sectors the hydrogeological boundaries are supposed to be buried, and thus evidenced with an appropriate symbol, and in which other ones, due to lack of control points, a high interpretation contribution by the hydrogeologist is needed (Fig. 8). In these latter sectors, the degree of objectiveness of the resulting boundary position is consequently lower.

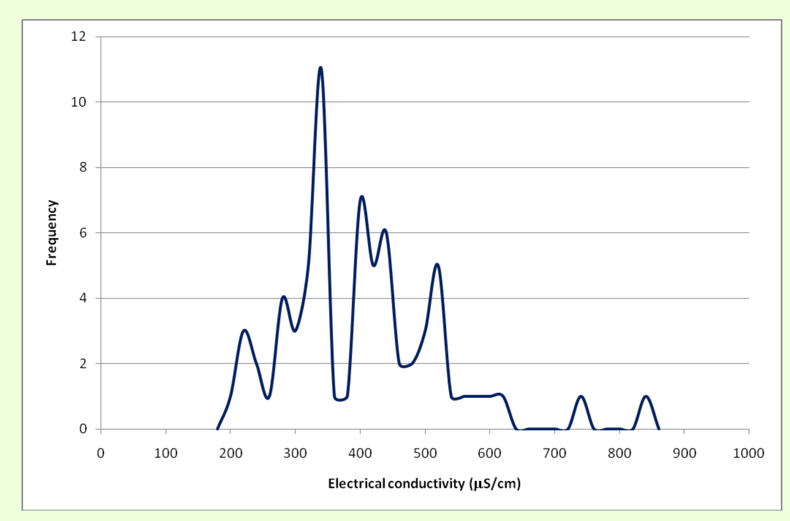

Fig. 3 – The analysis of the statistical distribution frequency of the EC allowed to check the reliability of the correlation between the value ranges associated to the main peaks (e.g., 200-380, 380-440, 440-510, 510-880 µS/cm) with specific hydrogeological complexes in the map (e.g., 200-440 are related to carbonate bearing complexes and 440-880 to flysch complex).

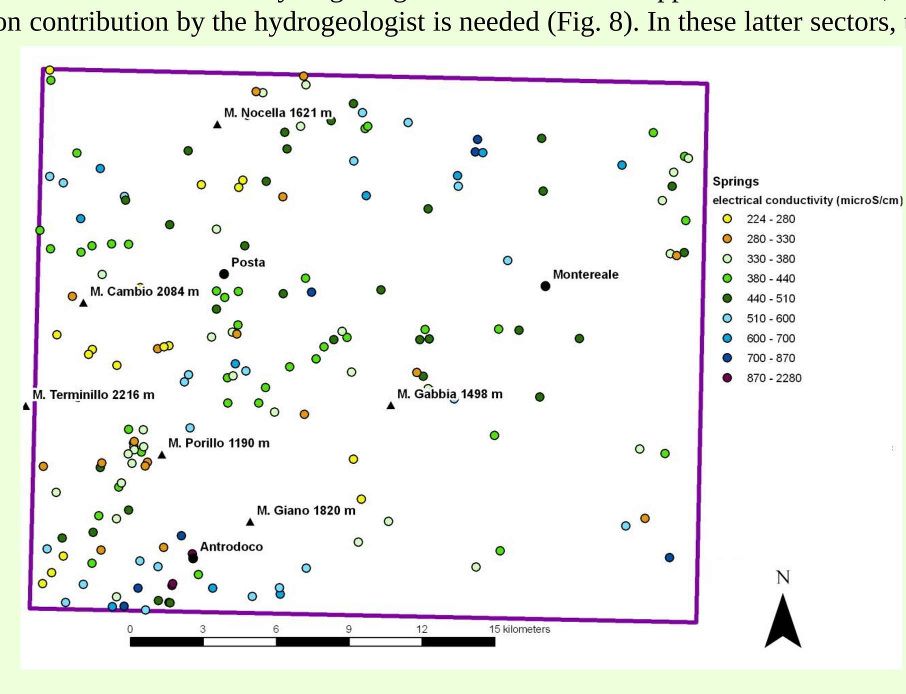

Fig. 4 – Layout of the shapefile reporting the registered control points and showing a map with the associated EC values expressed by a colour gradation scale.

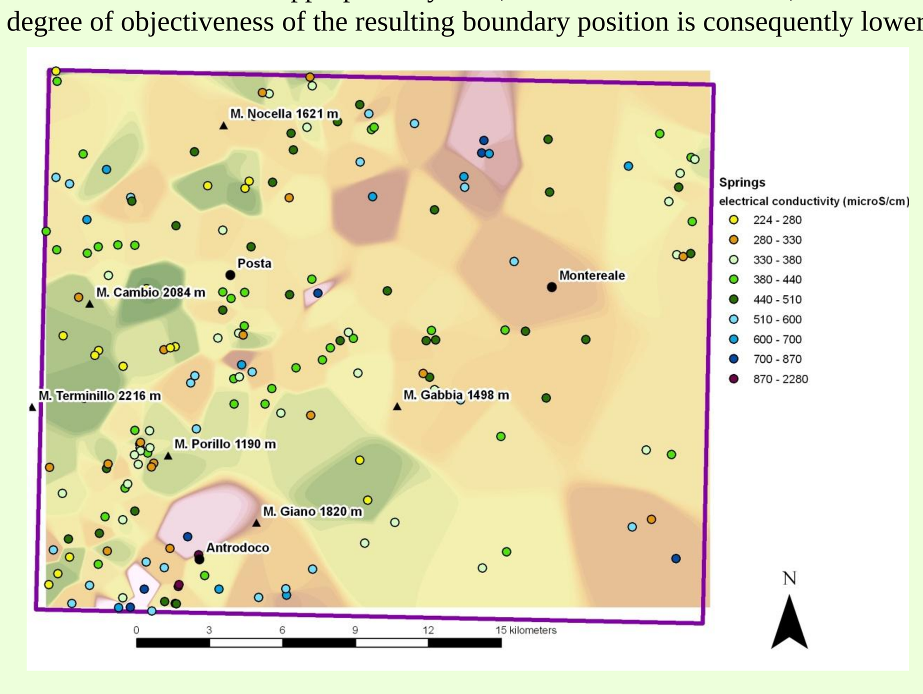

Fig. 5 – The EC value distribution in vectorial format has been submitted to an interpolation process toward a raster file, obtaining a series of influence areas of homogeneously grouped values of EC.

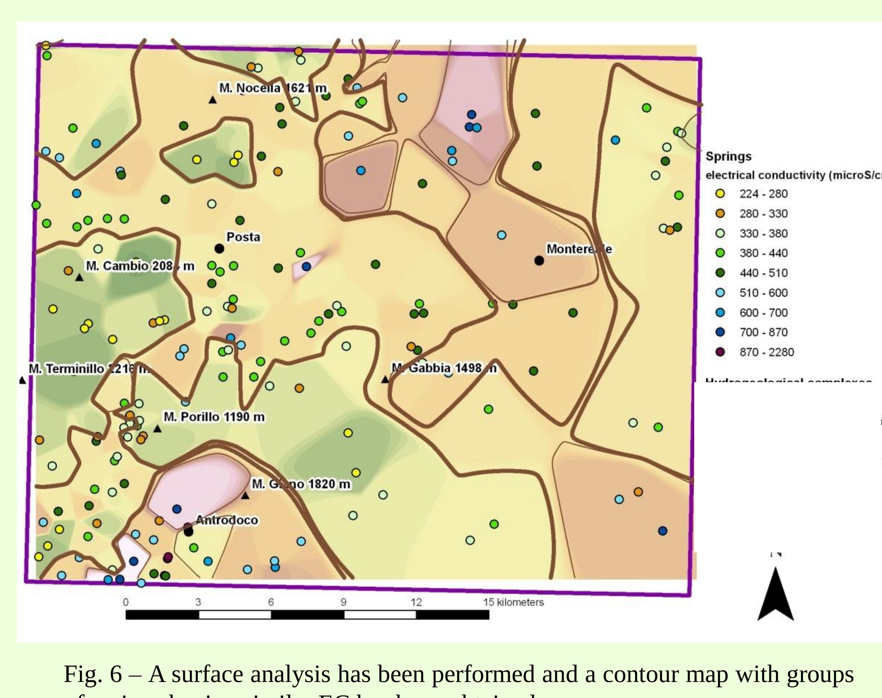

Fig. 6 – A surface analysis has been performed and a contour map with groups of springs having similar EC has been obtained.

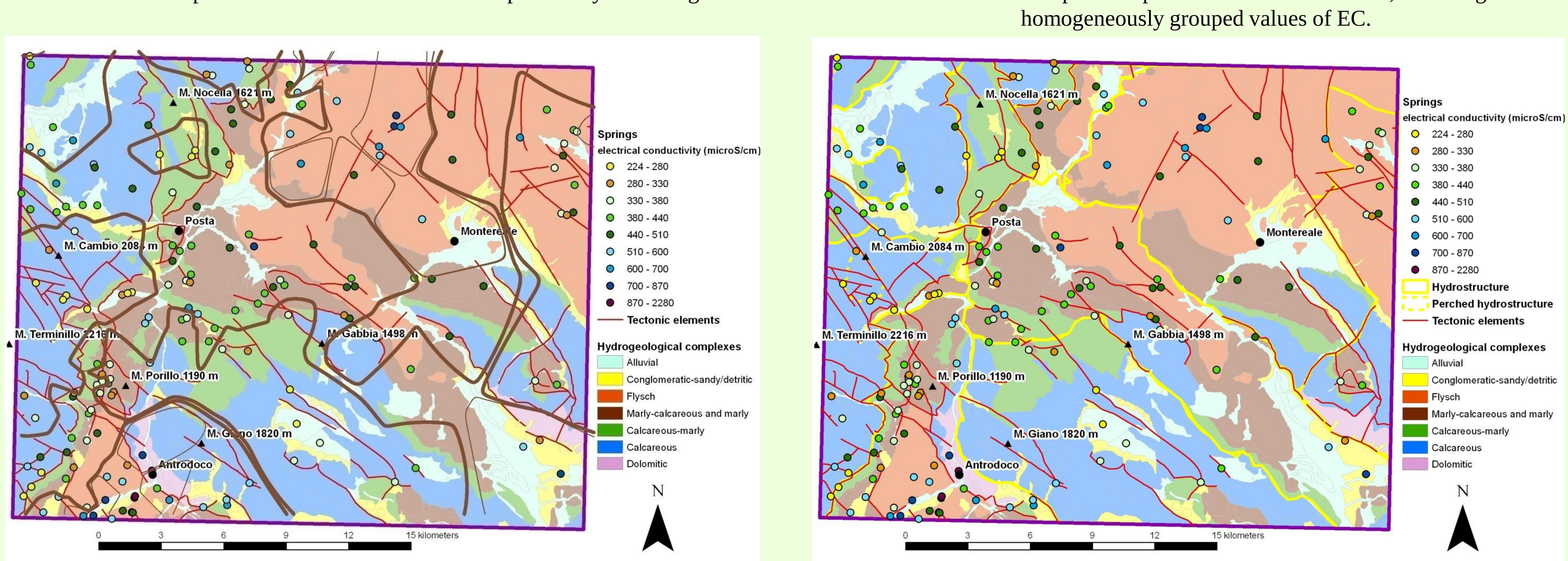

Fig. 7 –The superposition of the EC contour lines on a map representing the hydrogeological complex and the tectonic elements within the study area (left) has allowed the preliminary tracing of the hydrogeological boundaries (i.e., following the position of tectonic elements, geological boundaries, etc.) (right).

Fig. 8 – A detailed comparison between the obtained contour lines and the EC values distribution in the map has allowed to undertake the final tracing of hydrogeological boundaries and (left) to understand in which sectors the hydrogeological boundaries are actually buried under the alluvial cover, and thus evidenced with an appropriate symbol (dotted yellow line). In sectors where control points are lacking (e.g., M.Giano area) the final tracing of the hydrogeological boundaries may be very different from the computer assisted contour line drawing process results (right).

6. CONCLUDING REMARKS

The Geological Survey of Italy (SGI) is mandatory charged of the Italian hydrogeological cartography. In this respect, the SGI is currently involved in aspects regarding the delineation of hydrogeological boundaries, and thus the definition of unitary hydrostructures and GWBs. The problem of conducting this process by, as much as possible, objective criteria is a fundamental issue for the realization of consistent hydrogeological maps. The aim of the present work is to illustrate a feasible and objective approach preliminarily usefully applied for delineating hydrogeological boundaries in the test area included in the sheet map N.348 Antrodoco at 1:50.000 scale of the Italian hydrogeological cartographical production. Thus, the proposed approach is based on the application of informative algorithms, usually available in software GIS environment, allowing graphical elaboration on the spatial distribution of some hydrogeological parameters. The work has been conducted as follows:
-selection of the most representative hydrogeological parameter having the most homogeneous distribution within the studied territory (electric conductivity, EC, has been selected in this study);
-analysis of the appropriateness of the statistical distribution frequency of the EC values;
-preparation of a shapefile with the geographical and quantitative attributes of each registered water point of the control network;
- submission of EC values, organized in GIS vectorial format, to an interpolation process toward a raster file, obtaining a series of influence areas of homogeneously grouped values of EC, and elaboration of a surface analysis in order to obtain a contour map with appropriate isoconductivity equidistance;
-preliminary tracing of the boundaries (i.e., checking tectonic elements, geological boundaries, etc.). This phase was conducted by the superposition of the EC contour lines on a map representing the hydrogeological complex and the tectonic elements within the study area;
- final tracing of the boundaries (actually still in progress) after a detailed comparison between the obtained contour lines and the EC values distribution in the map (including evidencing of buried hydrogeological boundaries).

7. REFERENCES

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